

Resolved Atomic Super-clouds in Spiral Galaxies

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ABSTRACT

High quality data are presented of neutral hydrogen emission and absorption in the fields of eleven of the nearest spiral galaxies. Multi-configuration VLA observations have provided angular resolution of 6 arcsec (corresponding to about 100 pc at the average galaxy distance of 3.5 Mpc) and velocity resolution of 6 km s^{-1} , while accurately recovering the total line flux detected previously with filled apertures. Previous experience suggests that this physical resolution is sufficient to at least marginally resolve the H I super-cloud population which delineates regions of active star formation. A high brightness filamentary network of H I super-clouds is seen in each galaxy. Emission brightness temperatures in excess of 200 Kelvin are sometimes detected at large radii, even in relatively face-on systems. All galaxies display a systematic increase in the observed brightness temperature of super-clouds with radius, followed by a flattening and subsequent decline. In the few instances where background continuum sources allow detection of H I absorption, the indicative spin temperatures are consistent with the super-cloud brightness temperature seen in emission at similar radii. These data suggest substantial opacity of the H I in the super-cloud network.

Subject headings: galaxies: ISM — galaxies: kinematics and dynamics — galaxies: spiral — radio lines: galaxies

1. Introduction

It has become common practise to assume that the $\lambda 21$ cm line of neutral atomic hydrogen emission is in most cases an *optically thin* tracer of the atomic gas mass in external galaxies. A number of recent results are beginning to throw doubt on this conjecture. Careful imaging studies of H I absorption at low latitude in the Galaxy reveal *highly* saturated absorption associated with the velocities of spiral arms, with only lower limits to τ of 5 or 6 toward the supernova remnant Cas A (Bieging *et al.*, 1991) and the HII region complex W43 (Liszt *et al.*, 1993). Such highly saturated absorption is seen fairly uniformly over the several parsec spatial extent of these sources. These high opacities can not be attributed to velocity crowding along these lines-of-sight, since they are well removed from the “difficult” longitudes of 0, 70 and 180°, where Galactic rotation and geometry conspire to give a minimal gradient of line-of-sight velocity with Galactocentric distance. In addition, the absorption profiles have a high degree of structure in velocity, which is more consistent with an origin in discrete components rather than a smoothly increasing opacity with path length per velocity interval. Comparable H I opacities are therefore likely to be observed toward such spiral arm segments even if the Galaxy were viewed face-on. Since only a few low latitude lines-of-sight have received careful study, it is not yet possible to estimate the prevalence of such regions. A program to significantly extend the sample of well-imaged low latitude regions in H I absorption is now underway (Burton and Braun, 1995).

1.1. Emission Brightness as an Opacity Tracer

There is another, more accessible, tracer of the distribution of high opacity neutral hydrogen. The emission brightness itself, T_B , is tightly correlated with the absorption opacity, τ , in the solar neighborhood (Braun and Walterbos 1992, hereafter BW92). The simplest interpretation of this correlation is that on physical scales of about 1 kpc, a single temperature of cool gas is prevalent. This is not to say that only a single temperature *phase* of neutral gas is present on these spatial scales. On the contrary, Galactic lines-of-sight seem to exhibit as much as about 5 Kelvin of emission without detectable associated absorption, implying the existence of a widespread warm neutral phase with a kinetic temperature greater than about 5000 K. However, it is striking that all lines-of-

sight with more than about 5 K of emission do have detectable associated absorption suggesting that the warm neutral phase rarely attains a high column density, at least in the solar neighborhood. Neither is it the case that there is strict temperature equality of the cool gas over 1 kpc scales. The solar neighborhood data are contained in an envelope corresponding to a 50% variation about a well-defined mean cool phase temperature of about 110 K. This agrees with the peak brightness temperature seen directly in emission along the local Galactic plane. This general consistency is also borne out on a smaller scale. In a study of some 50 cross-cuts spanning associated molecular and atomic zones of optically identified Galactic dust lanes, Anderson *et al.* (1991) see evidence that the high brightness, atomic hydrogen envelopes of molecular clouds routinely have high H I opacity ($\tau > 1-2$) such that the *resolved* peak H I brightness temperature, T_B is identical to the H I kinetic temperature. Furthermore, they observe (but do not comment on) higher H I kinetic temperatures in their outer Galaxy objects ($R \sim 11$ kpc) than in either the solar neighborhood or the inner Galaxy. A recent analysis of the Galactic H I emission properties based on the Leiden/Dwingeloo survey (Braun, Burton and West 1996) has elucidated the distribution of peak T_B with radius in the Galaxy. A radial increase in T_B is observed out to about 10 kpc, with a subsequent decline. Simulations of the Galactic data are most consistent with high mean opacities of the gas over the radial interval over which the temperature gradient is found. This same radial gradient of both the peak T_B together with the *identical* H I kinetic temperature is seen in M31 via HI absorption and associated emission detected along multiple lines-of-sight (BW92) through the gaseous disk of that system. Kinetic temperatures of about 70 K are typical at 5 kpc radius in M31, while they increase to about 175 K at 15 kpc. The fact that widespread regions are observed in M31 with a high emission brightness in H I which is comparable to the implied local kinetic temperature suggests that regions of relatively high opacity in H I are similarly widespread.

1.2. Resolving H I Emission

A necessary condition for observing the H I kinetic temperature of an opaque region directly as an emission brightness temperature is that the region be resolved both spatially and in velocity. Since structure in Galactic H I is known to exist down to size scales of

less than a parsec, this may appear to be a rather elusive goal. The physical resolution available to BW92 in the case of M31 was 33 pc spatially and 5.2 km s^{-1} . This is comparable to the physical resolution in HI attained at the distance of the Galactic center with a 100 m filled aperture. Comparison of Galactic emission spectra at various physical resolutions (eg. Fig. 2 of Dickey and Lockman 1990) suggests that although detailed structures may certainly be under-resolved with a larger beam, the peak brightness is not substantially diluted even with 160 pc resolution (36 arcmin at 15 kpc). In a companion paper (Braun and Walterbos 1996) we consider in detail the degree to which H I emission structures in M31 have been resolved with the resolution of BW92. It is shown that spatial smoothing to 130 pc resolution gives a mean dilution of peak brightness of only 8% while velocity smoothing to 10 km s^{-1} gives rise to a 15% mean dilution of peak brightness. The major emission complexes, or atomic super-clouds, which give rise to high brightness H I emission regions apparently have typical dimensions larger than about 100 pc and line-widths which are only marginally resolved with 5 km s^{-1} . This assessment is in very good agreement with that of Elmegreen and Elmegreen (1987) who deduce a typical radius of 100 pc for H I super-clouds in the Galaxy and a typical velocity dispersion of 5 km s^{-1} .

The combination of spatial and velocity resolution necessary to resolve the H I super-clouds in galactic disks had never been applied to external galaxies beyond Messier 31. The study of M31 (Braun, 1990 and BW92) revealed higher brightnesses of H I than ever before detected in the Galaxy (up to 180 K) as well as the systematic increase of the H I kinetic temperature with radius noted above. What other attributes and trends are waiting to be discovered in galaxies of other morphological type? We set out to answer this question by selecting a sample for resolved H I imaging of the nearest external galaxies beyond the local group. An effort was made to span a large range of morphological type although the selection was limited primarily by the need for proximity. This is because a sufficiently high brightness sensitivity is necessary to actually detect the H I emission. For example, the A-configuration of the VLA could provide angular resolution at $\lambda 21 \text{ cm}$ of about 2 arcsec (corresponding to 150 pc at 15 Mpc) but would achieve a brightness sensitivity of only about 150 K per 5 km s^{-1} channel in an eight hour integration. When limited to modest

integration times of about eight hours, the practical limiting angular resolution is the 6 arcsec of the VLA B-configuration for which a brightness sensitivity of about 15 K is realized. This in turn imposes an upper limit to the distance of about 5 Mpc to maintain a spatial resolution of better than 150 pc.

The observations and data reduction of our nearby galaxy sample are described in § 2 of this paper. This is followed by a brief presentation of results in § 3. The reader is referred to a companion paper (Braun 1996, hereafter B96) for a more extensive analysis of the data.

2. Observations and Data Reduction

Neutral hydrogen observations of the eleven program galaxies were obtained with the VLA between March 1989 and November 1990. The B, C and D configurations (with effective integration times of about 7, 0.5 and 0.4 hours) were utilized to image a region 0.5 degree in diameter at 6 arcsec resolution for each of the eight Northern galaxies. In addition, a small hexagonal mosaic in the D configuration (with 0.4 hours effective integration on each of 7 positions) was used to image a 1 degree diameter field at 65 arcsec resolution. Similar resolution and sampling was obtained for the three southerly galaxies by observing in the BnA, CnB and DnC configurations. Observing dates, field centers and other particulars are summarized in Table 1. Namely, the galaxy name in column (1), the B1950 pointing center in (2), the observation dates for the three observed configurations in (3), (4) and (5), the central velocity and number of frequency channels in (6) and (7). The assumed inclination, position angle of receding line-of-nodes and major axis radius at which the blue optical surface brightness is 25 mag arcsec² (from de Vaucouleurs, de Vaucouleurs and Corwin, 1976, hereafter the RC2) is given in columns (8), (9) and (10). The galaxy type, approximate distance, total blue magnitude and luminosity are given in columns (11) to (14). Standard calibration and imaging techniques were used to produce a series of narrow-band images separated by 5.16 km s^{-1} over a velocity range of 330 km s^{-1} (or 660 km s^{-1} when necessary) centered on the nominal heliocentric systemic velocity of each galaxy. Since a uniform frequency taper was applied in the correlator, the effective velocity resolution was 6.2 km s^{-1} . A continuum image, formed from the average of line-free channels was subtracted from each image. A simulta-

neous deconvolution based on the Maximum Entropy Method (as in Cornwell 1988) was carried out on the seven pointings of the low resolution mosaic to determine the smoothest model brightness distribution at each velocity consistent with the data (corrected for primary beam attenuation) and the measurement noise. The model brightness distributions were then convolved with a two-dimensional Gaussian fit to the synthesized beam to which were added the residuals of the deconvolution. Since the zero level of each narrow-band image remains unconstrained due to the absence of total power data, the mean brightness in a region outside of the source was then subtracted from each. The good response to extended structure (as large as about 30 arcmin) obtained in this low resolution mosaic was incorporated into the series of high resolution images by replacing the inner Fourier plane of each (as in Braun 1988). The high resolution images were not subjected to deconvolution, since the good sampling, uniform weighting and Gaussian tapering (at 25 k λ) already provided a very nearly Gaussian instrumental response with a maximum near-in sidelobe level of only a few percent. The only substantial short-coming of this database, the so-called “short spacing bowl”, was accurately removed by including the low resolution mosaic data as discussed above. The image brightness scale (in Kelvin) was defined on the basis of integrating the actual instrumental response in elliptical annuli. This resulted in a small correction (about 5%) relative to the best fitting elliptical Gaussian beam. The best fitting elliptical Gaussian beam parameters as well as the beam integrals are listed in columns (2) and (3) of Table 2.

2.1. Images of Peak Brightness

Smoothed versions of the high resolution (6 arcsec) H I data-cubes were formed at resolutions of 9, 15, 25 and 65 arcsec. The absolute flux density and surface brightness scales are estimated to be accurate to better than 5%. The rms sensitivity in a single frequency channel is given in terms of flux density and surface brightness in columns (4) and (5) of Table 2. The surface brightness sensitivity after convolution to a circular Gaussian beam of 9, 15, 25 and approximately 65 arcsec is given in columns (6) through (9) of the table. Images were formed of the peak brightness observed along each spatial pixel and the corresponding line-of-sight velocity. Images of the peak brightness at the full spatial resolution are shown in panel (a) of Figs. 1–10 for all program galaxies but

NGC 4826. (Various images of NGC 4826 have appeared previously in Braun et al. 1994.) The noise properties of such peak brightness images are somewhat peculiar and deserve some explanation. When no detectable signal is present in the spectrum corresponding to any particular spatial pixel, a peak value of about 3σ is found from the 50 or so independent velocity pixels which make up that spectrum. When a signal is present at a level of greater than about 3σ it is detected with an uncertainty of 1σ . If the signal profile is broad relative to the velocity resolution, a positive bias level will be introduced due to the Gaussian noise statistics. It will be seen below that our velocity resolution of 6.2 km s $^{-1}$ is only sufficient to marginally resolve the emission line profiles at high spatial resolution so that the bias level of signals greater than about 4σ is negligible. Since only a single pointing position was observed for each galaxy at high resolution, the peak brightness images show the radially increasing 3σ noise floor due to the primary beam correction (corresponding approximately to a Gaussian of 30 arcmin FWHM). The obvious implication is that the detection level is a function of distance from the pointing direction. Since the typical 1σ noise at full spatial resolution is 18 K, the 3σ noise floor climbs from about 55 K at the pointing center to about 110 K at a radius of 1800 arcsec.

2.2. Images of Integrated Emission

Images of the integrated H I emission were produced at various resolutions by masking each cube with a positive 3σ threshold level of a lower resolution cube and then forming the sum. For example, the 9 arcsec resolution integral images shown in panel (b) of Figs. 1–10 were formed by imposing a mask based on a 3σ threshold level in the 25 arcsec resolution cube. Only at the lowest resolution of 65 arcsec, with masking by a 130 arcsec cube was the total (unmasked) flux recovered. These low resolution integral images are shown in panel (d) of Figs. 1–10. The use of a 3σ threshold level insured that no more than the total flux was obtained in the sum. In contrast, the use of a positive 2σ threshold level, produces a positive bias in the blanked sum of more than 20% in excess of the total line flux.

2.3. Images of Line-of-sight Velocity

The line-of-sight velocity of the peak emission brightness at 65 arcsec resolution is shown in panel

(c) of Figs. 1–10. This method of generating the projected velocity field is superior to the more commonly used method of generating the first moment since it is insensitive to the asymmetric profiles which are often observed at moderate spatial resolutions for galaxies of non-zero inclinations. This same advantage is gained over fits of a single Gaussian to the line profiles in addition to offering a greater robustness in cases of low signal-to-noise. With the high surface brightness sensitivity obtained at this low spatial resolution it is possible to determine the velocity field reliably out to the low column densities of the diffuse outer disk.

2.4. Emission Integrals

Total detected line fluxes were determined by evaluating the integral of the data cube at full spatial resolution within the region defined by a contour drawn at a peak brightness of 4 K in the 65 arcsec resolution peak brightness image. (Due to the method of data reduction these integrals are necessarily identical at spatial resolutions of 9, 15 and 25 arcsec.) The integral was also evaluated within the contiguous spatial region defined by the contour of zero integrated intensity in the 65 arcsec resolution mosaic database. These two values are listed in columns (10) and (11) of Table 2. In most cases 5 to 20% more line flux is detected with the second method. This is due to both the presence of extremely diffuse gas (with less than 4 K brightness) as well as the larger field of view of the mosaic database. In the case of NGC 4826, the 4 K threshold method only allowed detection of about 10% of the total flux. Recent total power measurements in the literature (as tabulated in Huchtmeier and Richter, 1989) generally lie between the values determined by the two methods above.

2.5. Search for H I Absorption

The continuum images of each field were searched for discrete sources toward the H I disks of the program galaxies. A two component least squares fit was then made to small regions (about 3 beam-widths, or 20 arcsec in diameter) in each continuum subtracted channel map to solve for the amplitude of the elliptical Gaussian source ($1 - e^{-\tau}$) and the amplitude of a constant interpolated background level (T_B) as a function of velocity. This method of deriving line-of-sight absorption and emission spectra was employed with success by Braun and Walterbos (1992) in the case of M31. An important difference between that study and the present one is the physical resolution.

The physical resolution available to BW92 for M31 was 35 pc and the dimensions of the fitting region were about 100 pc. As discussed in § 1, the scale size of major emission regions in M31 is about 100 pc, so that the fitting region was a reasonable match to this scale-size. In the present study the physical resolution available for our program galaxies was designed to be matched to this scale-size of about 100 pc but our fitting region is necessarily about 300 pc in extent. We therefore expect our derived spectra to have a higher fluctuation level due to confusion effects resulting from variable intensity levels within our fitting window. Inspection of the derived absorption and emission spectra reveals that this is sometimes the case. In these cases, the spatial baseline model was extended with inclusion of first or second order polynomial terms. The rms fluctuation level in the spectra in the presence of emission is still somewhat increased over that expected statistically. In the many cases of a slightly resolved continuum source this lost sensitivity is at least partially compensated by the detection of the source over several independent pixels.

3. Results

3.1. General Emission Properties: The Super-Cloud Network

Examination of the peak H I brightness images in panel (a) of Figs. 1–10 reveals how the distribution of atomic gas in our sample galaxies becomes decomposed at 100 pc linear resolution into a high brightness filamentary network of H I super-clouds. The continuity is best seen at low to moderate inclinations, while edge-on systems like NGC 55 and 4244 appear entirely filled as seen in projection. The super-cloud network corresponds globally to both the grand-design, as well as the flocculent, spiral arms traced by massive star formation and particularly by dust lanes in the various galaxies. A worthwhile comparison is that with the (B-O) color image of NGC 5457 in Schweizer (1976, his Fig. 3g). An interesting trend seen in many galaxies is for the lowest brightnesses to be observed at the smallest radii. This is most obvious in systems like NGC 3031, 4736 and 5457 which have a high luminosity stellar disk, but is also seen in NGC 247, 2403 and 7793. Extreme values of less than about 50 K are found at kpc radii in NGC 4736 for example. The opposite is also true, namely that the highest brightnesses occur at large radii. Emission brightnesses of 150 to 200 K are observed at large

radii in NGC 247, 3031, and 5457 with a clear systematic increase of brightness temperature with radius. *In fact, all of the sample galaxies show the same systematic behavior of the super-cloud brightness temperature with radius; an initial increase out to some radius, a flattening and a subsequent decline.*

3.2. Absorption Properties

The line-of-sight emission and absorption properties toward the 54 brightest continuum sources in the 11 observed fields are given in Table 3. The galaxy field is indicated in column (1) of the table, the B1950 position of each source in (2), the (deconvolved) major and minor axis dimensions and major axis position angle in (3), the observed values (without primary beam correction) of integrated and peak flux density in (4) and (5), the primary beam attenuation factor at the position of the source in (6), the rms error in the line-of-sight optical depth in a single velocity channel based on the peak source brightness in (7), the integral over the emission profile where the brightness exceeds 5 K in (8), the velocity interval over which the emission brightness exceeds 5 K in (9), the mean spin temperature or 3σ lower limit based on the ratio of emission to absorption in (10) (3σ lower limits are calculated using the values of integral emission and velocity width of columns 8, 9 together with the σ of column 7 divided by the square root of the number of contributing velocity channels), the maximum emission brightness in (11), the galactic disk radius intercepted by the line-of-sight in (12) and a code in (13) which indicates whether the continuum source may be intrinsic to the galaxy. Code R indicates a diffuse radio continuum morphology, code H the presence of H α emission at the galaxy redshift, code N indicates a nuclear source and a question mark indicates some uncertainty in the galactic identification.

The small number of randomly distributed background sources brighter than about 5 mJy/beam have only a very low probability of occurring along a direction which intercepts the super-cloud network of HI emission. The positions of the sources analyzed for the presence of emission and absorption are overlaid on the images of peak HI brightness and integrated emission in Figs. 1–10. Continuum sources associated with recent massive star formation within the galaxies, such as HII regions and supernova, while usually probing gas-rich lines-of-sight, only rarely have a sufficient continuum brightness to allow the detection of absorption. And even when they do, their location

within the galaxies confuses the interpretation, since only the unknown fraction of the gas seen in emission which lies between us and the continuum source can contribute to the absorption. Significant absorption is only detected in a small number of cases. Spectra for the lines-of-sight in NGC 55, 247, 2366, 2403 and 3031 are shown in Fig. 11, while the spectrum for the NGC 4826 line-of-sight has appeared previously in Braun et al. (1994). A high quality detection is made only in NGC 247 toward what appears to be a true background source, while 3 to 5σ detections are made toward HII region complexes within NGC 55, 2403 and 4826. Only statistical detection of absorption is seen toward a source intrinsic to NGC 2366 by summing the channels with emission brightness greater than 5 K. Comparison of the source locations with the peak brightnesses in panel (a) of Figs. 1–10 indicates that in all these cases but that of NGC 55, the continuum sources are located within local minima of the H I peak brightness, and therefore do not probe the super-cloud opacity directly. The bright nuclear source in NGC 3031 allows detection of faint absorption (5%) near a velocity of 0 km s⁻¹ which is very likely due to foreground gas in the Galaxy.

Comparison of column (10) of Table 3 with the images of peak brightness in panel (a) of Figs. 1–10 suggests that the spin temperatures and lower limits seen in absorption are consistent with the super-cloud brightness temperatures seen in emission at similar radii in each galaxy. Opacities toward the super-cloud network are therefore likely to be substantial.

3.3. Data Analysis

As indicated in the Introduction, extensive analysis of the database presented here can be found in a companion paper (B96). In that paper we present many properties of the H I super-cloud population as a function of radius in the various galaxies, including the fractional H I line flux, the surface covering factor and measures of the spatial and velocity compactness. We develop a detailed physical model in terms of radial profiles of gas density and temperature which can account for the observables quite successfully.

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TABLE 1
LOG OF OBSERVATIONS

Galaxy	R.A.(1950), Dec.(1950)	B or BnA	C or CnB	D or DnC	V_{Cen} (km/s)	N_{Ch}	Inc. (°)	PA (°)	R_{25} (")	Type	Dist. (Mpc)	B_T (mag)	L_B ($10^9 L_\odot$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
N55	00 12 24.00 −39 28 00.0	N/A	20-05-89	20-10-89	+140	64	80	110	972	Sc	2.0	8.22	3.2
N247	00 44 40.00 −21 02 24.0	04/05-03-89	20-05-89	20-10-89	+160	64	75	170	600	Sc	2.5	9.51	1.5
N2366	07 23 37.00 +69 15 05.0	19/28-03-89	29-11-90	01-12-89	+100	64	58	39	228	SBm	3.3	11.46	0.44
N2403	07 32 01.20 +65 42 57.0	19-03-89	29-11-90	01-12-89	+130	64	62	125	534	Sc	3.3	8.89	4.7
N3031	09 51 27.60 +69 18 13.0	16-03-89	29-11-90	01-12-89	−45	128	60	330	774	Sb	3.3	7.86	12.
N4236	12 14 21.80 +69 44 36.0	28-03-89	29-11-90	01-12-89	0	64	73	161	558	SBd	3.3	10.06	1.6
N4244	12 14 59.90 +38 05 06.0	23-03/02-05-89	29-11-90	30-11-89	+245	64	80:	233	486	Scd	4	10.60	1.4
N4736	12 48 32.40 +41 23 28.0	30-03-89	29-11-90	30-11-89	+305	64	33	305	330	Sab	3.8	8.92	6.1
N4826	12 54 16.90 +21 57 18.0	22-03-89	29-11-90	30-11-89	+415	128	66	300	282	Sab	3.8	9.37	4.0
N5457	14 01 26.60 +54 35 25.0	21-03-89	29-11-90	01-12-89	+230	64	27	40	810	Sc	6.5	8.18	35.
N7793	23 55 16.00 −32 52 06.0	04/05-03-89	20-05-89	20-10-89	+230	64	48	289	276	Sd	3.4	9.65	2.5

TABLE 2
DATA ATTRIBUTES AND RESULTS

Galaxy	a b p	Ω_B	ΔS_F	ΔT_F	ΔT_9	ΔT_{15}	ΔT_{25}	ΔT_{65}	$\int F_4 dV$	$\int F_0 dV$
(1)	(") (") (°)	(a.s. ²)	(mJy/bm)	(K)	(K)	(K)	(K)	(K)	(Jy-km s ^{−1})	(11)
N55	16.0 12.2 −15	220	3.5	10.9	3.98	0.93	1525	1525
N247	6.58 6.01 −10	61.6	1.9	21.1	12.7	6.47	3.78	0.76	765	860
N2366	5.67 5.66 −40	33.8	1.3	26.4	11.2	4.58	1.94	0.73	235	250
N2403	6.25 6.12 +66	48.0	1.2	17.2	9.73	4.85	2.52	0.68	1320	1440
N3031	6.13 5.84 −1	45.6	1.1	16.6	8.98	4.31	2.52	0.70	1455	1865
N4236	5.93 5.79 −38	49.2	1.2	16.8	8.98	4.85	2.52	0.63	550	610
N4244	6.84 5.95 −82	55.6	1.4	17.4	10.5	5.12	2.62	0.57	410	435
N4736	6.55 5.87 +85	48.8	1.3	18.3	9.73	4.58	2.23	0.58	43	70
N4826	6.49 6.10 −67	46.4	1.3	19.2	9.73	4.58	2.23	0.58	...	47
N5457	6.04 5.86 +69	44.8	1.1	16.8	8.23	4.31	2.43	0.62	1495	1880
N7793	6.98 6.06 −5	53.2	2.0	26.0	17.2	8.09	3.69	0.82	210	270

TABLE 3
HI ABSORPTION DATA

Galaxy	R.A.(1950), Dec.(1950)	a b p	S_{tot}	S_{pk}	PBa	σ_τ	$\int T_B dV$	ΔV	$\langle T_{sp} \rangle$	T_{Bmax}	R_{gal}	Cl
(1)	(2)	(") (") (°) (3)	(mJy) (4)	(mJy/bm) (5)	(6)	(7)	K km s ⁻¹ (8)	km s ⁻¹ (9)	(K) (10)	(K) (11)	(arcsec) (12)	(13)
N55	00 12 26.98 -39 29 00.8	26.3 9.0 150	19.93	8.22	1.00	0.43	4836	92.9	140±40	140	49:	R
	00 12 29.81 -39 29 14.6	38.3 27.4 156	52.09	8.09	1.00	0.43	4754	87.7	>175	100	52:	R
	00 12 43.79 -39 27 26.3	0.0 0.0 0	25.57	25.78	1.03	0.14	544	77.4	>65	20.3	308:	...
N247	00 44 21.01 -20 58 53.7	6.5 5.9 81	7.47	3.77	1.07	0.50	12.9	5.2	>2	2.7	931	...
	00 44 44.88 -21 07 36.2	6.0 2.9 154	47.4	31.4	1.06	0.06	1313	87.7	63±15	38.9	349	...
	00 44 53.89 -21 17 45.0	5.9 5.2 148	39.8	22.4	2.01	0.08	21.3	10.3	>12	2.7	980	...
	00 44 56.41 -21 05 50.1	0.0 0.0 0	5.62	5.07	1.06	0.37	84.1	25.8	>7	4.7	782	...
N2366	07 23 25.17 +69 17 29.0	4.5 4.4 101	8.70	5.38	1.00	0.24	1748	77.4	145±60	65	76	H
	07 25 06.93 +69 12 03.9	1.7 1.5 133	9.48	8.79	1.36	0.15	0	0	...	1.8	1822:	...
N2403	07 29 29.48 +65 34 33.7	6.6 2.6 52	19.26	12.12	2.45	0.10	13.3	5.2	>9	2.6	2091	...
	07 30 19.23 +65 59 44.7	9.1 2.1 54	17.20	9.19	3.06	0.13	0	0	...	1.5	1499	...
	07 30 24.47 +65 46 23.9	2.5 2.2 59	10.53	9.22	1.35	0.13	419	56.8	>63	30	739	...
	07 32 18.37 +65 43 21.3	14.5 5.1 81	10.27	3.12	1.00	0.38	1198	98.0	53±15	45.2	171	H
	07 32 41.72 +65 36 24.2	2.6 2.4 167	9.34	8.02	1.16	0.15	409	41.3	>62	25	554	...
	07 33 02.14 +65 47 14.0	2.2 1.0 77	11.13	10.36	1.15	0.12	223	36.1	>45	25	910	...
	07 33 09.08 +65 55 47.5	5.0 2.5 71	7.34	5.29	1.84	0.23	0	0	...	2.0	1852	...
	07 33 09.89 +65 55 52.3	7.4 2.6 116	8.92	5.29	1.85	0.23	0	0	...	1.8	1866	...
	07 33 56.27 +65 44 34.5	3.3 1.8 63	29.49	25.05	1.50	0.05	109	25.8	>63	6	1146	...
N3031	09 49 02.49 +69 17 59.2	7.0 6.4 11	33.77	14.99	1.60	0.07	89.7	25.8	>37	4	1394	...
	09 49 04.03 +69 18 11.3	13.5 6.4 43	31.39	8.63	1.58	0.13	87.8	25.8	>20	4	1371	...
	09 50 05.52 +69 13 02.5	3.5 2.3 169	5.39	4.36	1.23	0.25	44.5	15.5	>7	3	1067	...
	09 50 36.38 +69 31 57.2	5.5 4.8 174	10.00	5.76	1.82	0.19	178	25.8	>27	10	1100	...
	09 51 12.96 +69 24 04.4	0.0 0.0 0	3.13	3.04	1.09	0.36	469	56.8	>25	22	406	H?
	09 51 27.32 +69 18 08.3	2.3 2.0 141	90.28	79.87	1.00	0.014	17.7	5.2	>80	2.5	0.0	N
	09 52 46.82 +69 11 12.2	0.0 0.0 0	4.25	3.79	1.31	0.29	213	41.3	>17	10	654	...
	09 53 42.81 +69 24 48.7	5.8 3.6 154	23.80	14.71	1.70	0.07	81.7	25.8	>34	3	1634	...
	09 53 43.57 +69 25 05.7	6.1 3.6 32	16.97	10.15	1.72	0.11	64.2	20.6	>19	3	1658	...
N4236	12 13 03.90 +69 48 14.6	6.6 3.3 46	6.94	4.01	1.15	0.30	0	0	...	2	1113	...
	12 13 15.06 +69 50 22.3	3.1 2.7 133	8.21	6.60	1.18	0.18	45.1	15.5	>9	6	852	...
	12 14 13.97 +69 44 40.2	0.0 0.0 0	5.16	4.70	1.00	0.26	825	61.9	>59	33	128	H?
	12 14 14.07 +69 50 16.4	0.0 0.0 0	7.22	6.71	1.07	0.18	485	51.6	>55	28	418	?
	12 14 18.23 +69 45 41.1	4.5 3.9 153	12.0	8.00	1.00	0.15	863	72.2	>99	47	69	H
N4244	12 13 52.65 +37 49 20.9	9.8 3.4 91	10.9	5.39	3.40	0.26	0	0	...	2	4112:	...
	12 14 28.72 +38 11 26.3	7.7 7.1 5	14.0	5.95	1.22	0.24	0	0	...	2	7529:	...
	12 15 40.47 +38 16 34.2	6.0 3.8 146	10.1	6.31	1.74	0.22	0	0	...	1.5	3845:	...
N4736	12 48 31.93 +41 23 31.5	6.7 5.1 176	18.05	9.36	1.00	0.14	137	46.4	>21	4	0.0	N
	12 48 35.59 +41 23 24.3	11.1 5.0 178	7.69	2.87	1.00	0.45	430	87.7	>15	20	38	H
N4826	12 53 43.86 +21 59 48.9	7.9 7.7 6	5.68	2.25	1.17	0.58	0	0	...	2	519	...
	12 53 51.67 +21 58 38.6	0.0 0.0 0	21.0	13.6	1.08	0.10	0	0	...	2	415	...
	12 54 05.77 +21 44 19.7	0.0 0.0 0	10.0	9.93	1.65	0.13	0	0	...	1.5	1843	...
	12 54 16.28 +21 57 12.7	17.0 12.7 110	53.9	8.31	1.00	0.16	987	129	60±10	14	2	H
	12 54 23.23 +22 09 42.4	0.0 0.0 0	7.15	6.81	1.55	0.19	0	0	...	1.5	1740	...
	12 54 32.26 +22 08 28.1	2.3 2.0 15	9.58	8.56	1.47	0.15	0	0	...	1	1718	...
	12 54 32.50 +22 08 50.1	4.6 2.4 18	6.20	4.62	1.52	0.28	0	0	...	1.5	1770	...
	12 54 52.59 +21 45 19.3	0.0 0.0 0	7.22	7.18	1.84	0.18	0	0	...	1.5	1197	...
N5457	14 00 01.08 +54 43 17.1	6.8 4.3 76	33.3	17.8	1.85	0.06	0	0	...	2	985	...
	14 01 14.69 +54 28 49.5	12.2 9.3 17	6.40	1.51	1.12	0.71	735	51.6	>20	38	418	H
	14 01 31.59 +54 36 21.9	7.2 7.0 113	10.1	4.18	1.00	0.26	191	36.1	>18	20	72	...
	14 01 32.65 +54 36 15.4	6.4 5.6 168	7.80	3.87	1.00	0.28	197	36.1	>17	20	73	...
	14 01 39.13 +54 44 47.7	0.0 0.0 0	4.36	4.31	1.28	0.26	191	31.0	>19	30	590	...
	14 01 55.35 +54 33 26.5	10.6 6.0 44	16.8	5.84	1.04	0.19	872	67.1	>82	72	308	H
	14 02 09.48 +54 23 05.8	3.8 2.5 71	5.83	4.53	2.32	0.24	0	0	...	2	929	...
	14 02 15.94 +54 27 04.9	5.5 4.2 146	8.92	5.37	1.40	0.20	60.0	20.6	>10	4	738	...
	14 02 43.39 +54 38 09.4	9.5 7.0 148	8.94	3.08	1.44	0.36	814	56.8	>44	68	717	H
N7793	23 54 56.02 -32 54 09.7	5.7 4.7 0	6.67	4.09	1.04	0.49	303	61.9	>12	7	866	?

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Fig. 1.— Images of NGC 55. **(a)**. Peak brightness of neutral hydrogen emission as observed with full spatial and velocity resolution (about 100 pc and 6 km s⁻¹). **(b)**. Integrated neutral hydrogen emission at about 150 pc spatial (9 arcsec, except 15 arcsec for NGC 55) resolution. Masking for the integral was carried out at the 3 σ contour at about 400 pc (25 arcsec) resolution. **(c)**. The line-of-sight velocity of the peak brightness at 65 arcsec resolution. Iso-velocity contours are drawn at intervals of 15 km s⁻¹. **(d)**. Integrated neutral hydrogen emission at 65 arcsec resolution. The integrals have been converted to apparent column density under the usual (but incorrect) assumption of negligible optical depth. Contours are drawn at 1, 2, 4, 8, 16, 32 and 64 in units of 10²⁰cm⁻². As discussed in the B96, actual column densities are likely to be locally enhanced on spiral arm segments by factors of several. The linear grey scale has lower and upper limits as indicated. The filled cross marks the position of the pointing center. The un-filled crosses mark the position of continuum sources against which the data were analyzed for the presence of absorption. Note the trend for an increasing peak H I brightness with radius in the galaxies NGC 247, 3031 and 5457 as well as the extremely low peak brightnesses observed at small radii in NGC 4736.

Fig. 2.— Images of NGC 247 with panels as in Fig. 1.

Fig. 3.— Images of NGC 2366 with panels as in Fig. 1.

Fig. 4.— Images of NGC 2403 with panels as in Fig. 1.

Fig. 5.— Images of NGC 3031 with panels as in Fig. 1.

Fig. 6.— Images of NGC 4236 with panels as in Fig. 1.

Fig. 7.— Images of NGC 4244 with panels as in Fig. 1.

Fig. 8.— Images of NGC 4736 with panels as in Fig. 1.

Fig. 9.— Images of NGC 5457 with panels as in Fig. 1.

Fig. 10.— Images of NGC 7793 with panels as in

Fig. 1.

Fig. 11.— Line-of-sight H I absorption (top) and inferred emission (middle) toward continuum sources in Table 3 with (tentative) detections of absorption. The method of spectrum extraction is described in the text. A low spatial resolution (65 arcsec) emission spectrum is included (bottom panel) for reference.